Statistical learning for satellite Synthetic Aperture Radar image based Earth deformation observation

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Profile of candidate: *The Ph.D candidate should have good skills in mathematics/statistics and/or signal/image processing. Knowledge in Interferometry SAR is appreciated.*

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Ph.D subject description:

The systematic acquisition of and free access to Sentinel-1 A/B Synthetic Aperture Radar (SAR) images covering Europe every 6 days (every 12 days elsewhere) provide scientists with both opportunities and challenges for operational monitoring of Earth deformation by SAR image time series. For displacement estimation from SAR image time series, numerous multi-temporal Interferometry SAR (InSAR) methods, such as Small BAseline Subset, Permanent Scatterer Interferometry, SqueeSAR, Phase Linking methods, Multi-link InSAR, CAESAR, Least-Square estimator and EMI, have been extensively developed and implemented. Thanks to these methods, the accuracy of the displacement velocity estimation has been revolutionized to millimeters per year. However, these methods are mainly retrospective analysis tools and do not allow efficient gradual integration of new SAR images that arrive over time and it is necessary to restart part of or the whole displacement estimation processing chain, which would be prohibitively expensive in practice and does not answer the need for operational monitoring. Therefore, it is still necessary to develop more elaborated recursive multi-temporal InSAR methods allowing for efficient gradual integration of new arriving SAR images and considering non Gaussianity of data statistics.

In this Ph.D thesis, we aim to develop a novel robust and recursive multi-temporal InSAR approach for operational displacement estimation from SAR image time series. We consider the state-of-the-art Phase Linking approach as the baseline approach in which the sample covariance matrix of SAR image time series is fully exploited. First, we propose a sequential or recursive estimation of the covariance matrix of SAR images, taking into account the structure of the covariance matrix that is directly related to the decorrelation properties of the targets under observation. Second, we integrate temporal decorrelation models (with possible unknown parameters) providing prior information on the structure of the covariance matrix in the sequential or recursive estimation process in order to improve the efficiency. We then deploy the Expectation – Maximization (EM) algorithm to estimate jointly the unknown model parameters and the covariance matrix in an iterative way. The displacement time series can be later obtained from the properly estimated covariance

matrix.This displacement times series isfinally used to estimate physical parameters of the deformation source in depth. However, missing data can exist in the displacement time series, mainly due to the coherence loss that results in unreliable displacement estimations. Data gaps can hinder the full understanding of the phenomenon under observation. Therefore, the third objective of this Ph.D consists of imputing missing data in displacement time series, with the missing data mechanism taken into account by assuming statistical laws and estimating the parameters that describe these statistical laws.

We consider the ''Piton de la Fournaise'' and Merapi volcano test sites as proving ground for the developed approach in this Ph.D thesis. Both descending and ascending Sentinel-1 A/B acquisitions are available. GPS measurements from permanent GNSS stations are also available for results comparison and validation.

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